[0029] FIG. **2** is a transmission electron microscopy (TEM) image showing nanopatterns in various forms;

[0030] FIG. **3** illustrates a method of manufacturing a nanostructure according to an exemplary embodiment;

[0031] FIG. **4** illustrates a method of manufacturing a nanostructure according to an exemplary embodiment;

[0032] FIG. **5** illustrates an operation of manufacturing a nanostructure according to an exemplary embodiment;

[0033] FIG. **6** is a cross-sectional view illustrating an optical device including a nanostructure according to an exemplary embodiment;

[0034] FIG. **7**A is a graph showing an absorbance spectrum of an optical device according to an exemplary embodiment; and

[0035] FIG. **7**B is a graph showing photocurrent characteristics of an optical device according to an exemplary embodiment.

[0036] FIG. **8** illustrates a nanostructure including nanopatterns formed in a direction;

[0037] FIG. **9** illustrates a nanostructure in which distances between nanopatterns are adjustable;

[0038] FIG. **10** illustrates a nanostructure including nanopatterns having a core-shell structure; and

[0039] FIG. **11** illustrates a nanostructure including nanopatterns formed in a plurality of regions.

DETAILED DESCRIPTION

[0040] Reference will now be made in detail to exemplary embodiments which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the exemplary embodiments are merely described below, by referring to the figures, to explain aspects of the present description. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. Expressions such as "at least one of," when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0041] In the drawings, widths or thicknesses of layers or areas illustrated in the attached drawings may be exaggerated for clarity of the specification. Throughout the specification, like reference numerals denote like elements. Meanwhile, the embodiments described below are merely exemplary and may include various modifications. It will also be understood that when an element is referred to as being "on" another element, it can be directly on the other element, or intervening elements may also be present.

[0042] FIG. **1** illustrates a nanostructure according to an exemplary embodiment. Referring to FIG. **1**, the nanostructure may include a lower structure **10**, a two-dimensional material layer **12** formed on the lower structure, and nanopatterns **14***a* and **14***b* formed on the two-dimensional material layer **12**.

[0043] The lower structure **10** may be an object on which a nanostructure according to an embodiment is formed, and may be a substrate formed of any of various materials. Examples of the substrate include a glass substrate, a polymer substrate or a semiconductor substrate such as silicon. Also, the substrate may be a conductive substrate, such as metal or a conductive metal compound, or may be an insulating substrate, such as a silicon oxide or a silicon nitride. Also, the substrate may be transparent, opaque, or semi-transparent.

[0044] The two-dimensional material layer **12** may have a single-layer structure or a half-layer structure in which atoms have a predetermined crystalline structure, or may have a structure formed of multiple atom layers. The two-dimensional material layer **12** may include a carbon nanomaterial or a metal chalcogenide based material. The metal chalcogenide based material may be a transition metal dichalcogenide (TMDC) material including a transition metal and a chalcogen material. The transition metal may be at least one of Mo, W, Nb, V, Ta, Ti, Zr, Hf, Tc or Re, and the chalcogen material may be at least one of S, Se, and Te. The TMDC material may be represented by, for example, a formula of MX_2. M may be a transition metal such as Mo, W, Nb, V, Ta, Ti, Zr, Hf, Tc, or Re, and X may be a chalcogen element such as S, Se, or Te. In detail, the TMDC material may be MoS_2, $MoSe_2$, $MoTe_2$, WS_2, WSe_2, WTe_2, ZrS_2, $ZrSe_2$, HfS_2, $HfSe_2$, $NbSe_2$, $ReSe_2$ or the like. Also, the metal chalcogenide based material may not be represented by MX_2. For example, a transition metal chalcognide material such as a compound formed of Cu, which is a transition metal, and S, which is a chalcogen element, may be represented by CuS. The carbon nanomaterial may include graphene. the graphene may be in the form of a planar sheet in which carbon atoms are connected in a hexagonal shape. The two-dimensional material layer **12** may include a single-layer of graphene or multiple layers of graphene. The graphene layer may be directly formed on the lower structure **10**. Also, the graphene layer may be formed on a substrate other than the lower substrate **10** using a chemical vapor deposition (CVD) method or a pyrolsis method and may then be transferred onto the lower structure **10**.

[0045] The nanopatterns **14***a* and **14***b* may be formed of Au, Ag, Cu, Cr, Pt, Pd or an alloy thereof or of other metals. The nanopatterns **14***a* and **14***b* may include a first nanopattern **14***a* and a second nanopattern **14***b*. The first nanopattern **14***a* and the second nanopattern **14***b* may be formed of the same material. For example, if the first nanopattern **14***a* is formed of Ag, the second nanopattern **14***b* may also be formed of Ag, and if the first nanopattern **14***a* is formed of a material including Au and Ag, the second nanopattern **14***b* may also include Au and Ag.

[0046] The nanopatterns **14***a* and **14***b* may have any of various shapes, and may be, for example, spherical; cube-shaped; or polygonal, including a triangular pyramid shape, or polygonal pillar-shaped. Also, the nanopatterns **14***a* and **14***b* may be rod-shaped and have a length that is longer than a cross-sectional width thereof. Examples of cross-sectional shapes of such rod-shaped nanopatterns are not limited and may be a circle, an oval, or a polygon. Also, the nanopatterns **14***a* and **14***b* may have the same shapes but different sizes. In the nanostructure according to the present embodiment, the nanopatterns **14***a* and **14***b* may have different shapes, that is, may include nanopatterns that have different forms or different sizes. For example, the first nanopattern **14***a* may be spherical, and the second nanopattern **14***b* may be rod-shaped, as shown in FIG. **1**. Surface plasmons that are generated in a nanometer-sized metal structure, such as the nanopatterns **14***a* and **14***b*, are referred to as localized surface plasmon resonance (LSPR), and an LSPR frequency may vary according to the shape of the nanopatterns **14***a* and **14***b*. For example, a spherical nanopattern formed of Ag may